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# Interflow Network Coding Approaches for Data Heterogeneous Unicast Sessions in Wireless Networks

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## ABSTRACT

The authors investigate the problem of reliable unicast transmissions in wireless ad hoc and WLAN/WiMAX networks. Currently, approaches using network coding show several-fold gain in terms of bandwidth efficiency over the traditional technique, "store and forward". However, most of these approaches have assumed that all the information flows have the same packet size, while the others consider transmission flows with different size packets, then overcome the size-difference issue by padding more dummy data into the smaller size packets. In their approach, by exploiting the size differences of packets on different flows, the authors introduce a new technique at the relay node/access point/base station to improve network bandwidth efficiency. In particular, a symbol-adjusted technique has been proposed in creating coded packets to improve the reliability of transmissions. Both analytical and simulation results show that the proposed technique significantly improves the network performance over the current technique.

## KEYWORDS

Network Bandwidth Efficiency, Unicast Transmissions, Wireless Ad Hoc Networks, WiMAX, WLAN

## 1. INTRODUCTION

Network coding (NC) is a recent routing approach pioneered in the paper by Ahlswede & Cai (2000), in which an intermediate router may generate (encode) output data based on incoming data. It has been shown that this approach can achieve multicast/broadcast capacity of a network. Recently, NC technique has also been applied successfully to increase throughput in wireless ad hoc networks. A classic example first proposed in the paper by Wu & Chou (2004) for efficient information exchange in a wireless ad hoc network is shown in Figure 1. Here, two nodes $N_1$ and $N_2$ are assumed to exchange information through node R. Packet a sent by node $N_1$ to node $N_2$ is relayed through node R. Similarly, packet b sent by node $N_2$ to node $N_1$ is relayed through node R. As a result, node R has both packets *a* and *b*. In an existing wireless ad hoc network, node R has to perform two transmissions, one transmission for sending packet a to $N_2$, and another one for sending packet *b* to $N_1$.

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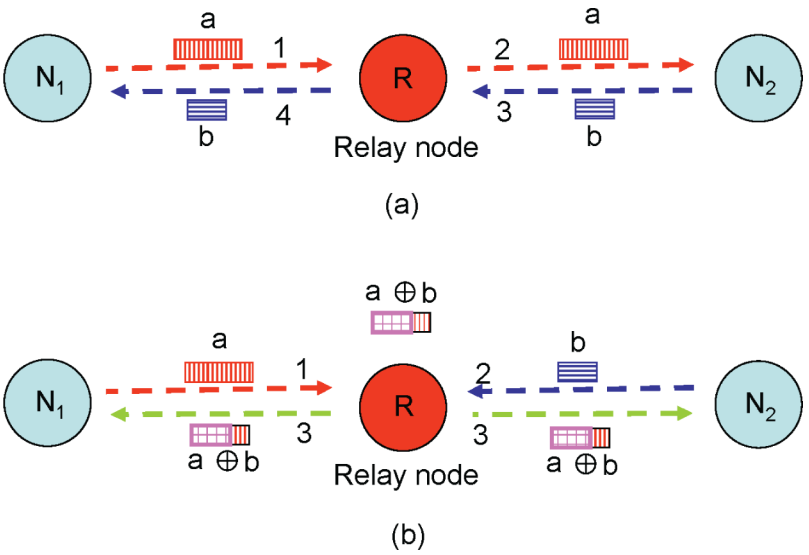
**Figure 1. An example scenario of information exchange in wireless ad hoc network**




Now consider a NC technique. Here, upon receiving a and b, R can broadcast packet a ⊕ b to both $N_1$ and $N_2$. Since $N_1$ has a, it can recover b as b = a ⊕ (a ⊕ b). Similarly, $N_2$ can recover a as a=b⊕(a⊕b). Figure 1(a) shows the current technique with 4 transmissions while Figure 1(b) shows the NC technique in which the number of transmissions has been reduced to 3.

In the approaches using NC technique, we have assumed that both a and b have the same size to utilize NC technique as in (Katti, S. & Katabi, D., 2005). When considering different size packets, some other works proposed a simple method that can help to overcome this issue by padding more "0" into the smaller size packets (Katti, S. & Rahul, H., 2006; Dong, Q. & Wu, J., 2007).

On the contrary, by exploiting the size differences of the packets on different flows, in this paper, we propose a new technique to improve network bandwidth efficiency. Especially, at the relay node, more redundancies will be added into the smaller size packet to make all packets the same size before combining them to generate a coded packet (CP). The information recovery probabilities at receivers that want the smaller size packets will be increased.

The organization of our paper is as follows. In Section 3, we describe the system models and transmission protocols in the context of ad hoc and WLAN/WiMAX networks when using NC technique. Packet encoding and packet error probability are presented in Section 4. In Section 5, we provide an analysis on network performance in terms of bandwidth efficiency on different network scenarios. Simulations and discussions are provided in Section 6. Finally, we conclude with a few remarks and future work in Section 7.

## 2. RELATED WORK

This paper is a follow-up work of Tran & Nguyen (2008). In this work, we proposed a joint network-channel coding technique for both wireless broadcast and unicast sessions. By using exhaustive search method and lookup table we can find the optimum amount of redundancy for each transmission packet to maximize the network bandwidth efficiency. Our work is rooted in the recent development of network coding for wireless ad hoc networks (Wu & Chou, 2004; Katti, S. & Katabi, D., 2005; Fragouli, C. & Boudec, J. & Widmer, J., 2005; Deb, S. & Effros, M., 2005). In the paper by Wu & Chou (2004), the authors proposed the basic technique that uses XOR of packets to increase the

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